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Collaboration Interface Supporting Human-Autonomy Teaming for Unmanned Vehicle Management

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COLLABORATION INTERFACE SUPPORTING HUMAN-AUTONOMY TEAMING FOR UNMANNED VEHICLE MANAGEMENT

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Advances in technology are leading to envisioned operational concepts that team a single operator with autonomy to manage multiple heterogeneous unmanned vehicles (UxVs). Several autonomy decision aids have been integrated into a prototype control station with innovative human-autonomy interfaces that allow multiple UxV management via high-level commands called "plays". Each play defines the actions of one or more UxVs, often in response to a mission event or task. This paper describes recent enhancements made to a Task Manager tool to better support operator-autonomy collaboration. After mission events are signaled in chat, corresponding tasks are communicated by an intelligent agent via pictorial icons designed to facilitate rapid retrieval of necessary actions. These icons also enable direct manipulation control functionality. The Task Manager supports shared awareness across human and agent team members by summarizing the relative priority, recency, and completion status of mission tasks.

Several autonomy advancements were integrated into a control station prototype referred to as "IMPACT" (Intelligent Multi-UxV Planner with Adaptive Collaborative/Control Technologies) to flexibly team a single human operator with autonomous decision aids performing a base defense mission (Draper, Calhoun, Spriggs, Evans, & Behymer, 2017; Draper, et al., 2018; Figure 1). To support human-autonomy teaming in IMPACT, a "play-calling" method is used that enables a single operator to develop and execute plans quickly for multiple heterogeneous unmanned vehicles (UxVs). This involved the design and implementation of a comprehensive suite of play-based interfaces to support calling plays, reviewing/revising the autonomy-generated play plan(s), and monitoring play execution. For example, when an IMPACT operator calls a play to achieve air surveillance on a building, an intelligent agent recommends a UxV (based on estimated time en route, fuel use, etc.), a cooperative control algorithm provides an optimal route to get to the building (taking into account no-fly zones, etc.), and an autonomics framework monitors the play's ongoing status (e.g., alerting if the UxV won't arrive on time).

Figure 1. IMPACT Control Station Prototype.

The operator is able to call plays through the selection of a corresponding play icon that represents both the vehicle type(s) that will be assigned and the high-level action of the vehicle(s) (i.e., play type; see Figure 2). IMPACT's play-calling interfaces also facilitate operator-autonomy communication on mission details to optimize play parameters (e.g., current visibility) as well as support operator/autonomy shared awareness (e.g., a display showing the tradeoffs associated with multiple agent-generated courses of actions). This adaptable extended play-calling approach is novel in its flexibility in providing fine-grained control whereby the operator can rapidly specify the level of automation along multiple dimensions, as well as seamlessly transition between control states. Additional details on the play-related interfaces are available (Calhoun, Ruff, Behymer, & Mersch, 2017; Calhoun, Ruff, Behymer, & Frost, 2018).

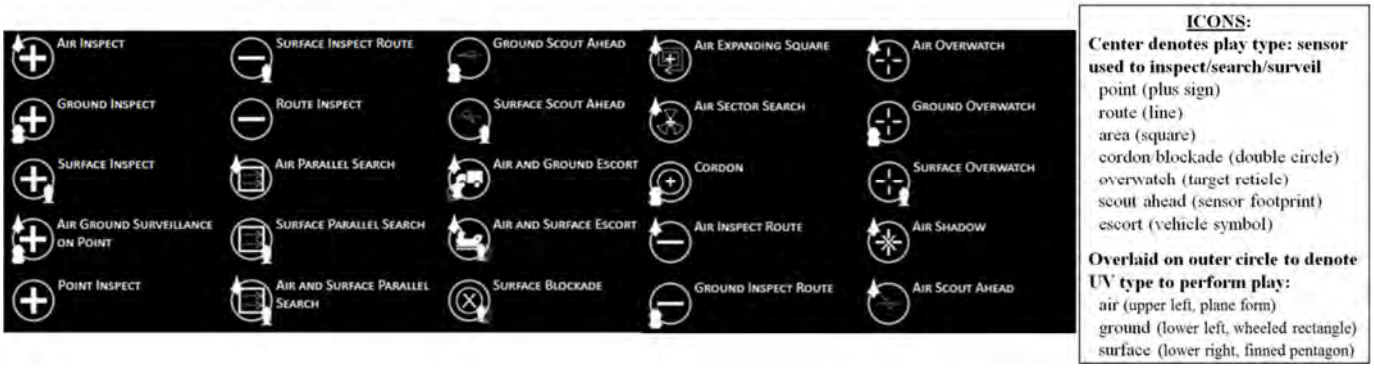

Figure 2. Icons that specify play and UxV type.

Play icons are accessible from several interfaces. A dedicated play-calling interface provides a categorized list of all 25 pre-defined base defense-mission related plays. Play icons can also be selected from a radial menu that is presented upon a right-mouse click of a target (i.e., location or other entity) or a UxV symbol on the map; the radial menu filters plays to present just those relevant to the selection. When utilizing these play-calling interfaces the operator has to specify, at a minimum, *what* type of play and *where* the play should be executed.

A third interface that includes selectable play icons is the Task Manager. This interface has been recently enhanced to facilitate operator-autonomy coordination. The Task Manager utilizes an agent that constantly monitors incoming communications (e.g., chat rooms) for mission events. For each identified mission event, the agent creates a corresponding task for the operator. Each task includes one or more subtasks that should be addressed in order to consider the higher-level task complete. The agent also suggests actions the operator could take to complete these subtasks, such as play calls that could be utilized (see Figure 3).

Figure 3. Representation of the relationship between mission events, tasks, subtasks, and plays.

Task Manager Interface

Left Pane of Task Manager

The left pane is persistent on the monitor and is where the high-level tasks are represented (see Figure 4). Each task has a corresponding mission-coded icon that has been determined in previous research to be intuitive and discriminable (Bartik, et al. 2017). The task icons utilized to date in support of IMPACT's base defense mission are illustrated in Figure 4.

The Task Manager uses rows (see Figure 4) to help organize multiple tasks that have varying priority since operational tasks will likely vary in priority. For IMPACT, each type of mission task has a pre-assigned priority in relation to the overall base defense mission, and this determines how the corresponding icons populate the four rows. The top row is for tasks that need immediate attention, specifically responding to events that indicate there is an active threat or attack on the base. The second row is for base defense activities that are performed as needed during normal operations (e.g., a specific threat has not been detected). Random Anti-Terror Measures (RAMs), or tasks that randomize base activities and help maintain base safety, are assigned to the third row. The question marks in the fourth row indicate that the agent detected queries in communications, each of which the operator can leverage the system in order to generate a reply. The magnifying glass icons are presented in experiments to task operators to provide mission information (as a measure of situation awareness). The number below each icon indicates how many of that task type have been identified (e.g., two queries in the fourth row). As tasks of the same priority are identified, they are added in respective rows from the right.

Figure 4. The left pane of Task Manager showing agent generated tasks in four rows, each row decreasing in priority. The following identifies the mission tasks, from left to right, for each row. Row 1: crowd forming, gate runner, mortar fire, perimeter breach, explosive device. Row 2: building/fence alarm, overwatch (provide air coverage), escort, eyes on (location), suspicious vehicle/watercraft, unidentified vehicle/watercraft. Row 3: 360 check, interval (temporal) check, listening post, and show of force. Row 4: queries and information retrievals (two each).

Each of the task icons is presented within a circle. The circle's line coding designates if that task needs to be completed by the human operator (solid line) versus the intelligent agent (dotted line). A dashed-dotted line for the circle indicates that the task (with multiple subtasks) requires action from both human and agent team members (e.g., the left most alarm icon in the second row of Figure 4).

The Task Manager's left pane in Figure 5 shows one of the task icons highlighted with a square outline and shade coding to indicate that the operator has selected the associated event, an activated alarm. (Thus these icons enable direct manipulation control functionality.) There are also two additional smaller icons to the right of the task icon by which the operator can delete the task (by selecting "X" the task is removed from the Task Manager and recorded in a separate log) or assign the entire task to the agent partner (by selecting the lightning bolt icon). The selection of a task icon in the left pane also brings up the right pane.

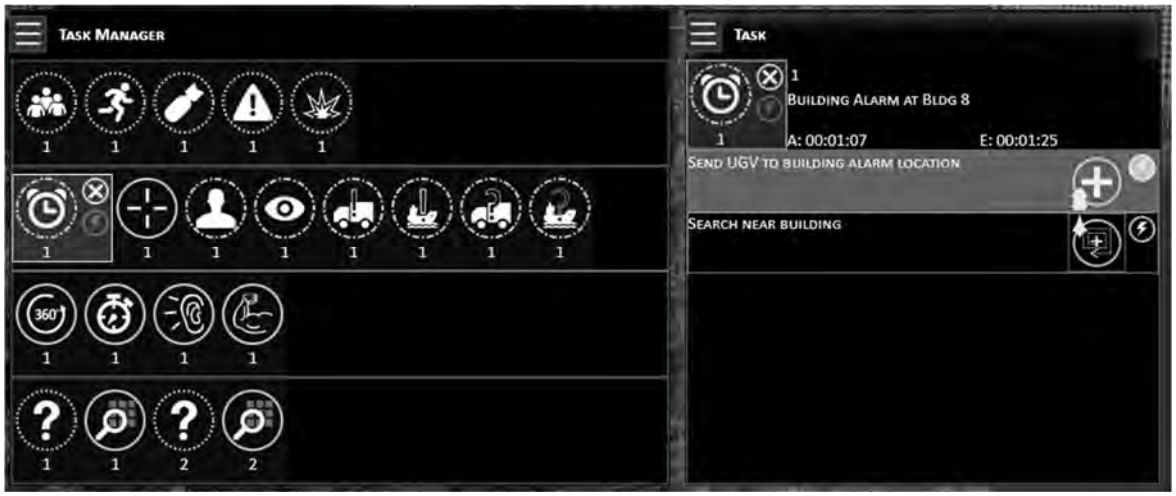

Figure 5. Illustration of Task Manager. Left pane shows a selected building alarm task. Right pane shows associated subtasks and suggested plays for the selected task.

Right Pane of Task Manager

The right pane displays additional symbology related to the selected mission task. At the top, the task icon and functions from the left pane are repeated along with the exact chat that triggered the creation of the task (e.g., "Building Alarm at Bldg 8") and two time fields (A: time when the task was added and E: time elapsed). Below this header, the agent's recommended subtasks are listed. The first subtask, as show in the right pane of Figure 5, is to send an unmanned ground vehicle (UGV) to the alarm location. A play that can be leveraged to complete this subtask, a ground point inspect, is represented on the right side of the row with a selectable play icon. The lightning bolt icon to its right allows the operator to assign that subtask to the agent. When selected, the lightning bolt will become highlighted and the row will be shaded. For example, the top row in Figure 5 indicates that the "Send UGV to building alarm location" subtask is being completed by the agent team member.

The second row in Figure 5 states that a search near the building with the activated alarm needs to be completed. In this example, the agent suggests an air expanding square search play as a means to complete this subtask. Also, the row is not shaded indicating it has not been completed by the operator. Once the operator completes an assigned subtask (i.e., calls a play in

response), the row will become shaded (the lightning bolt will not be highlighted because it was completed by that operator and not the agent). When the task is completed via a play call, the initiated play and related task information is represented elsewhere (e.g., Active Play interface and map symbology). The right pane will remain open with all subtasks shaded until the operator closes the pane, deletes the task all together, or clicks on another task.

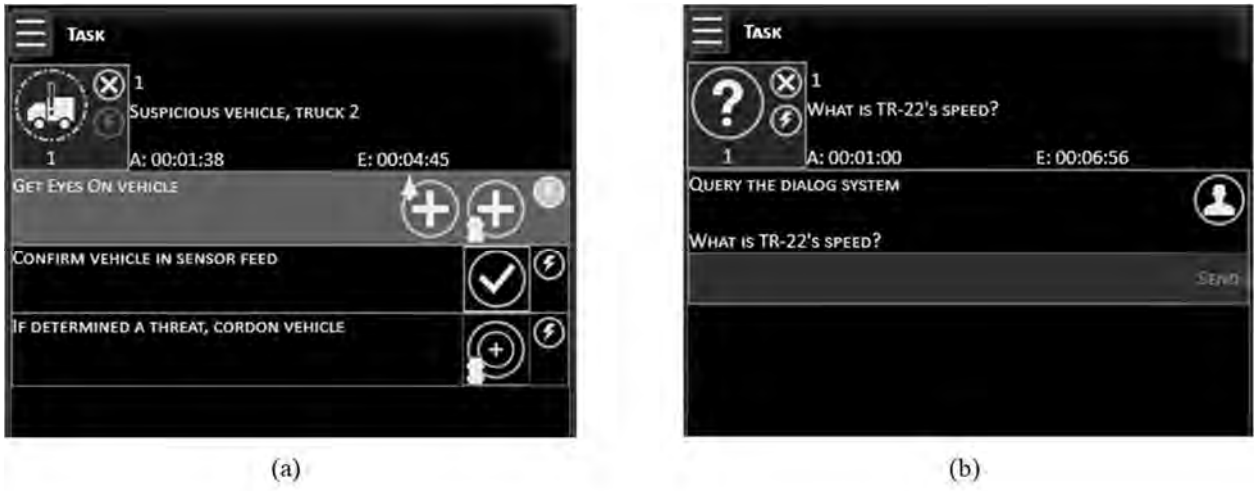

Figure 6. (a) Right pane for a suspicious vehicle task. (b) Right pane for a query task.

Figure 6 illustrates the right panes of two additional tasks. The suspicious vehicle task has two subtasks that can be completed with play calls (the first and last subtasks; see Figure 6a). However, the second subtask requires communication with a sensor operator to confirm that the target is visible in the sensor feed. The operator can mark this subtask as complete by clicking the checkmark icon on the far right. Figure 6b shows the right pane for a query task. Instead of a list of subtasks, the query is shown along with a text box that can be used to send the response. By clicking the "person" icon, the operator can receive a response to the query from the agent.

Summary

In contrast to the other IMPACT play-calling interfaces in which the operator needs to specify *what* type of play and *where* the play should be executed, the intelligent agent, based on an ongoing analysis of mission events, proposes the *what* and *where* in the Task Manager and helps the operator team with autonomy in performing base defense. Moreover, it provides priority-based task organization and the control functionality by which the operator can assign tasks/subtasks to the agent for completion (Frost, Bartik, Calhoun, Spriggs, Ruff, & Behymer, 2018). With additional refinements, the interface could support coordinated distributed operations with other autonomy-aided human operators managing different UxV assets. The Task Manager is also a candidate interface to communicate and coordinate actions for envisioned autonomy advancements that result in the agent's ability to suggest pre-emptive tasks/plays to better posture the base for defense.

It should be noted, however, that the Task Manager does not function in isolation. The Task Manager's play recommendations are based on pre-established parameters for each type of task and these parameters can be refined (both prior and during play execution) to meet current

mission considerations by employing other play-related interfaces. Also, upon play execution the Active Play interface is instrumental in maintaining a shared understanding between human and autonomy team members on the status of all ongoing tasks (see Calhoun, et al., 2018). Regardless, the Task Manager is paramount to play-based multi-UxV management because it facilitates rapid retrieval of necessary actions (and their relative priority), expedites execution of necessary mission-related actions, and provides a mechanism for sharing the workload between the human and autonomy team members.

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